

# Differential Maintenance

## Management Guide

The differential plays a critical role within a machine's drive train by changing the direction of the power coming from the transmission 90 degrees to allow the axles to be driven. They also allow speed and torque differences between the left and right axles. When a machine is turning, the differential lets the outside wheel move at a faster speed than the inside wheel, allowing for easier turning and less wear on tires or tracks. The gears in the differential also provide speed reduction and torque increases.

Establishing and following a preventive maintenance program is a key factor in guaranteeing fewer failures, more uptime, and better machine resale value.

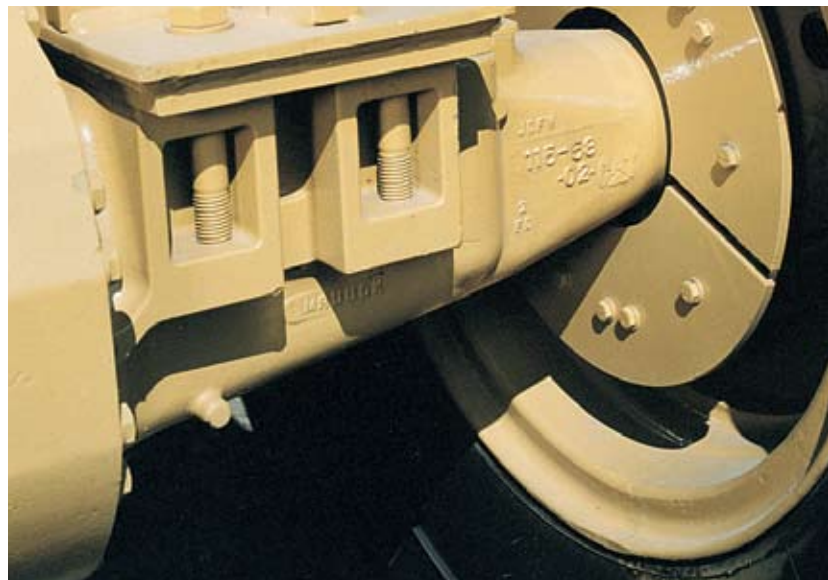
This guide discusses preventative maintenance, repair management, and highlights the components that wear and fail in the differential. By understanding these topics, you could minimize owning and operating costs while maximizing your productivity.



# Contents

<i>Overview</i> .....	3
<i>Preventive Maintenance</i> .....	4
<i>S•O•S<sup>SM</sup> Services</i> .....	5
<i>Contamination Control</i> .....	6
<i>Repair Management/Repair Indicators</i> .....	7
<i>Differential Steering</i> .....	8
<i>Bearings/Gears</i> .....	9
<i>Key Components/Component Durability</i> .....	10
<i>Repair Options/Scheduling and Record Keeping</i> .....	11
<i>Expect More from the Experts</i> .....	12

This **Differential Maintenance Management Guide** offers information, tips and ideas but is not intended as a technical manual or a substitute for the advice and recommendations of our parts and service experts. By using this manual to help you understand Differentials and following the recommendations in your Operations and Maintenance manual, you can maximize the productivity, service life and value of your Cat<sup>®</sup> machines.



# Overview of Differentials

The differential will decrease the speed and increase the torque as needed for each wheel's relative motion. When the machine is turning, the differential will supply the needed adjustments to the wheels allowing the outside wheel to move at a faster pace than the inside wheel. Caterpillar designs and manufactures its differential components with these demands in mind, using testing processes that replicate actual applications. In order to get the productivity and life you demand, it is important to maximize the life of these components by properly managing and maintaining them.

The key functions of a differential are:

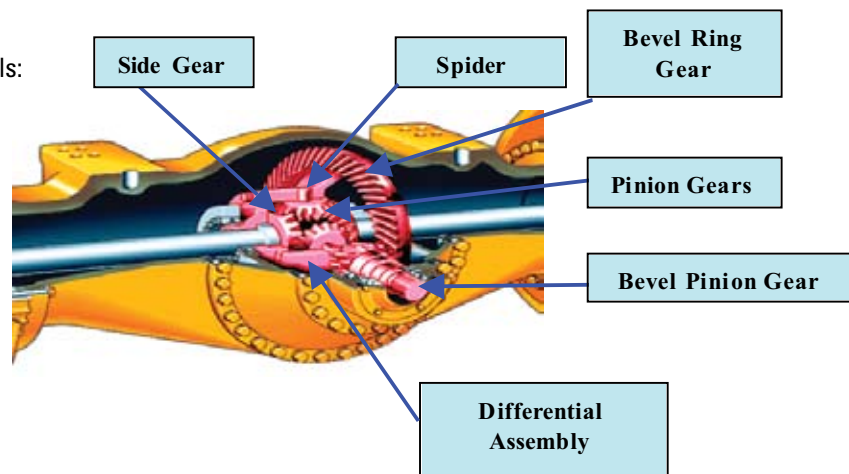
- Transferring power coming from the transmission to the left and right axle shafts
- Balancing the power according to the demand of each wheel
- To transmit the power to the wheels while allowing them to rotate at different speeds
- Gears in the differential further reduce speed and increase torque to drive the rear wheels

The key components of the differential are:

- Differential Assembly- Turns the spider and pinion gears that mesh with the side gears, turning the axle shafts
- Pinion Gears- Transmits power from the spider to the side gears that are attached to the axle shafts
- Side Gears- Splined to the axles and are driven by the pinion gears
- Spider- Serves as the mounting for the pinion gears, and rotates with the differential assembly
- Bevel Pinion Gear- Driven by the drive shaft
- Bevel Ring Gear- Meshes with the bevel pinion gear, and is mounted to the differential assembly

There are four types of Differentials:

- Standard- As Shown
- Limited Slip
- No Spin
- Locking



## Optimize Equipment Life

The key components in differential preventive maintenance include quality oils and filters, regular S-O-S Oil Analysis and contamination control.

### Preventive Maintenance:

- Allows you to schedule downtime and plan for maintenance and repair costs
- Helps prevent major failures, including failure of related parts
- Saves you money because you can often repair before failure
- Reduces total downtime
- Maximizes parts reusability
- Optimizes equipment life to keep your machine productive and on the job
- Increases machine resale value

### Proper Oil Use

The three main functions of oil are to provide cleaning, cooling and lubrication. Modern Cat drive train systems feature new metals, elastomers and paper disc materials which may have advanced lubrication needs, requiring you to change oil regularly, properly, and use the right drive train oil to achieve top performance.

### Use the Right Drive Train Oil

Cat differentials experience high gear and bearing loads and temperatures. In these conditions, it is important gears and bearings are protected.

It is essential that components be run in the correct oil. Always consult your Operations and Maintenance Manual for the specific oil needed. The publication SEBU6250, Caterpillar Machine Fluids Recommendations, can be used for additional verification on oil recommendations.

**Cat TDTO (Transmission Drive Train Oil)** is specially formulated to increase the life and performance of your Cat drive train components.

This oil:

- Reduces transmission slippage
- Controls brake chatter
- Provides greater machine rimpull
- Increases friction material life up to 45 percent

Cat TDTO surpasses the TO-4 specification requirement and is specified as factory fill for all Caterpillar machine compartments where TO-4 is the primary recommendation.

**Cat TDTO-TMS (Transmission Multi-Season)** is a multi-season formulation of TDTO. This Caterpillar exclusive is a partially synthetic lubricant that eliminates the need to change oil at seasonal intervals. As a result you use the oil for its full life, so there's less used oil disposal and less downtime for maintenance. Cat TDTO (TMS) has shown improved transmission performance in cold weather for machines with electronic controls.

Cat recommends TDTO for transmissions, final drives or differentials, torque converters, and brakes where TO-4 specification oils are recommended for use; and recommends TDTO -TMS to avoid unnecessary oil changes in climates with widely ranging ambient temperatures.

**Cat FDAO (Final Drive Axle Oil)** was developed specifically to protect gears and bearings in bevel gears, differentials, final drives and axles that do not contain friction materials.

Cat FDAO is the preferred lubricant for Cat Off-highway truck front wheels, differentials and final drives. It is compatible with Cat final drives and axles

that previously specified TO-4 lubricants and do not contain friction material.

Cat FDAO has the following qualities:

- Compatible with Cat Transmission Drive Train Oil (TDTO)
- Excellent protection against rust and copper corrosion
- Minimizes foaming for increased lubrication
- Low oxidation rate for improved oil life
- Maintains desired viscosity and film strength
- Provides reduced wear from debris particles suspended in the oil



**Cat Gear Oil** offers maximum protection against the following damage: scoring of the gear teeth, pitting of the gear teeth, and pitting of the parts in roller bearings.

Cat Gear Oil provides:

- Excellent stability under high temperature conditions
- Superior low temperature performance.
- Protection against rust and corrosion

Some applications require additives for the extreme pressures that can occur at the edges of the components. For these applications, Cat Gear Oil provides the extra protection. Cat Gear Oil should not be used in compartments that specify TO-4 or TO-4M oil.

# Importance of S-O-S Oil Analysis

Scheduled Oil Sampling is a crucial part of machine management. Oil sampling at scheduled intervals validates your maintenance procedures, tracks what is going on inside of the equipment and forecasts wear-related problems. Our S-O-S Oil Analysis program is well recognized for its ability to detect potential failures before they occur. Each S-O-S Services test is designed to reveal specific information about the condition of Caterpillar® products.

The four types of analysis are below:

- Wear Metal—monitors and tracks metal wear particles, contaminants and oil additive package elements
- Oil Condition—compares used oil to new oil to see if it is providing adequate lubrication and protection
- Oil Cleanliness—determines if abrasive contaminants are causing accelerated wear
- Oil Contamination —detects water, glycol, or fuel in oil

## Advantages of using S-O-S Services

Surveys have shown that there are many benefits to using our S-O-S Oil Analysis program:

- Experts can provide analysis and interpretation of trends and can forecast any excessive wear concerns
- Test results are available within 24 hours after receipt of the sample



- Easy-to-understand test report, which calls for specific action and/or makes carefully outlined recommendations
- Saves time and money by identifying trouble spots before they become major failures

S-O-S Services help you avoid complete failures. Often an adjustment or replacement of a single part, based on S-O-S Services findings, can prevent a small problem from growing into a major repair. S-O-S Oil Analysis is different from other oil analysis programs because it focuses on component condition, not just oil condition. Since only Caterpillar knows the exact design of your Cat drive train system, we can help you analyze S-O-S

reports, determine what additional tests need to be performed, and recommend the proper corrective action better than other oil analysis programs.

## Particle Count

Particle count is another way of assuring oil cleanliness. When used in conjunction with fluid analysis, particle counting can be a valuable tool in reducing failures in differential systems. The particle count instrument counts the number of particles in several different size ranges, from as small as two microns to over 100 microns. It measures both metallic and non-metallic particles and provides an early warning of abnormal component wear and contaminant ingestion.

## S-O-S Oil Analysis Example: Typical Differential Combinations:

Primary Element	Secondary Element	Potential Wear	Probable Problem Area/Causes
Iron	Chromium	Gears, Anti-friction bearings	Pre-load problem (if no water or dirt is evident)
Aluminum, Chromium	Iron	Sleeve bushings	Wearing out, or previous contamination

# Control Contamination, Reduce Overall Operating Costs

Dirt, sand, grit and even the finest dust can cause problems when they find their way into the differential. They cause parts to wear faster, making them more prone to premature failure.

There are four ways contamination can get into machine systems:

- 1) Contaminants can be built in during manufacturing and assembly operations.
- 2) Contaminants can enter during servicing and maintenance procedures.
- 3) Contaminants can enter with new fluid.
- 4) Contaminants can enter during operation through pitted shafts, broken breathers, worn seals and other trouble spots.

Fortunately there are steps you can take to prevent fluid contamination. An effective contamination control program is made up of many small steps that help maintain fluid cleanliness and reduce opportunities for contaminants to get in machine systems. Caterpillar recommends a four-part contamination control program consisting of:

- 1) Clean fluids
- 2) Clean components
- 3) Clean facilities
- 4) Clean shop-repair processes



By following these steps, you will be better prepared to control contamination, reduce overall operating costs and keep your Cat equipment performing at its best.

### Filters

Control contamination inside your differential through the use of Cat fluid filters. By changing filters regularly and properly, and by selecting the right filters, you maintain system cleanliness, reduce component wear and lower costs.

The use of fluid filters in differentials varies by machine type. Filters can be found on the 797 and 793 off-highway trucks and machines using a common reservoir system such as backhoe loaders. For further information on selecting the correct fluid filters, consult your machine's Operation and Maintenance Manual.

## Managing Repairs

**Repair Management** is only one factor that influences your owning and operating costs. You should also address operating technique and application as well as preventative maintenance.

In the area of operating technique:

- Avoid high-speed direction changes
- Avoid backing over obstructions
- Avoid extreme braking
- Operators should adequately warm-up the machine
- Pay attention to warning lights
- Do daily walk around inspections

Application concerns might involve:

- Ambient temperature
- Design of haul roads and repetitiveness of the work

### Repair Indicators

There are two types of indicators: planned and problem. Planned indicators are part of a good Differential Maintenance Management Program that will give you before-failure repair options to lower your operating costs. Planned indicators are those that are performed or checked routinely such as S-O-S Oil Analysis, Technical Analysis, service meter hours,

service history and SOMA software. Problem indicators are usually found during inspection and include noises, leaks, overheating, and poor performance. Even with excellent maintenance, eventually repairs will be needed. However, problems can be caught early by performing daily inspections and responding quickly to repair indicators.

### Differential Repair Indicators

Below is a list of planned and problem indicators for Cat differentials, along with possible causes and repair options.

Planned Indicators	Description	Options
S-O-S oil Analysis	S-O-S Services provide the best insight into the internal differential wear and potential failure	Customer/Dealer Discussion
Service Meter Hours	When visiting the customer, be sure to keep track of machine's service meter	S-O-S Services Customer Dealer Discussion
Experience -Observation and discussion	Talking with your machine's operator can reveal many potential differential problems	Repair Determination Discussion
Service History	Service history indicates how frequently routine maintenance is performed	Customer/Dealer Discussion
Fuel Consumption	Indicates when a piece of equipment is operating at less than optimum efficiency	Customer/Dealer Discussion
Site Operations Maintenance Advisor (SOMA)	SOMA is a software that assesses customers operating and maintenance practices and provides component life estimates	
Problem Indicators	Possible Causes	Options
Bent or Damaged Lines	External damage	Technical Analysis Inspection Repair Determination Discussion
Unusual Noises (When Traveling Straight)	Worn gears/bearings Ring & pinion Require Adjustment Dirt entry Low fluid level	Technical Analysis Inspection Repair Determination Discussion Customer/Dealer Discussion
Unusual Noises (When Turning)	Worn differential case assembly Worn spiders Worn spider gears	Technical Analysis Inspection Repair Determination Discussion Customer/Dealer Discussion
Vibration	Gear failure Spider failure Differential failure Bearing failure	Technical Analysis Inspection Repair Determination Inspection Customer/Dealer Discussion S-O-S Services
Debris on Magnetic Plug	Contamination entry (dirt/debris) Extended oil change period Wrong oil used Worn gears/bearings	S-O-S Services Customer/Dealer Discussion
Leaks	Worn/damaged seals (pinion/differential) Worn bearings	Repair Determination Discussion Customer/Dealer Discussion
Overheating	Wrong oil used Low fluid level Worn or damaged seals	Technical Analysis Inspection Repair Determination Discussion S-O-S Services Customer/Dealer Discussion

Keep in mind determining the cause is usually easier said than done. A visual exam may identify the type of damage, but it may not aid in recognizing what is causing the problem. Remember, if you merely replace the failed component without finding and fixing the root cause, the replacement component will most likely endure the same wear and damage as the original.

# Understanding Differential Steering



### **Differential steering uses 3 planetary gear sets and a hydraulic motor to change the speed of each track.**

This system delivers uninterrupted power to both tracks during turns. Power from the transmission is delivered through the bevel gears to three planetary gear sets, then to the final drives and tracks. By adding power to one of the planetary gear sets, the motor adds (or redistributes) power to the steering differential, and by its direction of rotation, speeds up one track and slows down the other to make turns. By rotating one direction, it makes a right turn, and by rotating the other direction, it makes a left turn. Thus the hydraulic motor determines the direction and degree of the turn.

The results are turns of any degree, from slight to sharp, without interruption in power. The operator turns, reverses direction and changes speed ranges using one hand on a single tiller.

This Caterpillar-patented steering system is available in the Caterpillar D6R through D9R, and Challenger Tractors.





## How Bearings and Gears Work

Bearings are used in the differentials to maintain position and alignment of gears and shafts, and to minimize friction, heat and wear. They also carry the weight of the vehicle and payload, subjecting them to very high loads and temperatures. Cat bearings have precision surfaces that are separated by a film of lube oil.

It is critical that the surface of the contact areas retains an adequate oil film thickness to prevent metal-to-metal contact with the mating part.

Caterpillar bearing design is application driven, which means we offer the correct bearing for the application.



**The basic function of gears in the differential is to transfer power from the drive shaft to the axle shafts.**

Loads are transferred through gears by gear teeth pushing against each other. Gears used in the differentials are put through a carburizing and hardening process. This creates a durable outside surface enabling them to carry very high loads for thousands of hours. The gears are machined and precision ground to exact tolerances, making it crucial for the lubricating oil to be at its proper level

to avoid metal-to-metal contact. The heat treatment, material and machining processes used on gears are based upon the specific application.



### **Causes of Premature Bearing Failure**

In order to maximize bearing life, it is important to eliminate the four primary causes of premature failure:

- Improper installation— Bearings are not properly installed with the correct pre-load
- Improper tolerances—Width tolerances are incorrect for the application
- Overload (fatigue)—Resulting from machine overloading or long hours of use
- Contaminated lube oil— Causes accelerated surface pitting and premature failure

### **Causes of Premature Gear Failure**

There are five primary causes of premature gear failure:

- Pitting from surface fatigue— Normal end-of-life failure mode; however, consistent overloading accelerates this
- Contaminated lube oil— Causes accelerated surface pitting and cracking
- Gear tooth bending fatigue— Result of severe gear overloading
- Improper alignment—Creates unbalanced loading and contact on gears
- Improper lube oil—Increases surface wear

# A Look at the Key Components

Understanding how differentials work and wear is key to maximizing component life. Differential repair parts can be broken up into three groupings. They are:

**Level I**—fastest wearing parts, not reusable

- Anti-friction bearings
- Seals and gaskets
- Duo-cone seals

**Level II**—slower wearing parts, possibly reusable

- Plates
- Discs
- Gears

**Level III**—longest life, designed not to be replaced

- Housings and axles.

In order to correctly identify failure modes for differentials, it is necessary to understand how the component works, the causes of its premature wear or failure, and the maintenance steps that can be taken to minimize the causes of wear and failure.



## Key steps to improving component durability

### Clean Lube Oil

By far, the most common and preventable cause of component failure is due to contaminated lube oil. To ensure components run in clean lube oil, it should be built clean, installed clean and operated clean.

### Correct Lube Oil

It is essential to the component's life to be run in high-quality lube oil. Using the correct lube oil will improve component wear life up to 40% in some applications.

### Proper Installation and Assembly

Components are built with specific tolerances and preloads. Proper installation and assembly practices are absolutely essential to component life.

### Avoid Overload and Fatigue

Two factors that dramatically accelerate subsurface fatigue and component life are excessive loads and rolling resistance.

### Replace Parts Before Failure

Differential piece parts do not have an infinite life. After being run for thousands of hours at high loads and temperatures, the material will eventually fatigue. Thoroughly inspecting the components results in detecting defects and deterioration before they fail completely and damage other vital components.

# Selecting the Right Repair Option

Selecting the right repair option is a way to lower owning and operating costs.

### Before-Failure Repairs

Repairing before failure gets your machine back to work sooner and costs two to three times less than after-failure repairs. Our before failure repair options:

- Help prevent major failures and failure of related parts
- Maximize parts reusability designed into many differential parts
- Allow you to schedule downtime and plan costs
- Maximize equipment life and productivity

Differential repair options:

- Reseal—required when oil leaks are discovered during inspections

- Rebearing and reseal—signaled by excessive leaks, elevated S-O-S results or target hours
- Before-failure overhaul—involves rebuilding the entire differential

### After-Failure Repairs

Repairing before failure is the best way to reduce your downtime and costs. However, if your differential system does fail, we are in the best position to help you control costs and save time. Part replacement costs are kept to a minimum, using Cat Parts Reusability Guidelines and replacing only damaged components. Possible options include using Exchange or Cat Reman components. Cat Reman components are available from inventory, offer same-as-new performance, and carry the same warranty as new components at a lower cost.

After-failure overhaul is recommended when large pieces of metal are discovered during magnetic plug inspections, when failure occurs or when broken parts are discovered during before-failure procedures. It includes removal and replacement of the entire differential and axle group.



### Scheduling and record-keeping

Good scheduling means maintenance, inspections and planned repairs are done on time to prevent differential failures caused by overlooked maintenance. You can also view S-O-S Oil Analysis results on-line.

### Record-keeping

By developing an accurate machine record-keeping system, you can identify high-cost or problem areas, track work flow, control costs, and increase machine resale value. An accurate record-keeping system documents drive train history by detailing component life and cost information. We can help you set up manual record-keeping and work order systems, or we can help you install computer software programs to perform scheduling, checklists and other record-keeping functions.

# Expect More From the Experts

## Maximize the Life of Your Differentials

For any machine to be safe, reliable and productive, regular preventive maintenance is vital. It is the most cost effective way to keep your differential operating at peak performance. If you take care of your differential, then gears and shafts can last through multiple rebuilds and the overall differential life increases. Take a proactive approach by planning for scheduled downtime, maintenance and repair costs. When you plan, you save money and time—and who couldn't use more of each?

### **CAT® DEALERS DEFINE WORLD-CLASS PRODUCT SUPPORT.**

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